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## ABSTRACT

The advancement of microcomputer technology has reached the point where color monitors and color computer software are fast becoming the norm in our information society. Color is another channel for communication, and can be used for enhancement of both aesthetic characteristics and productivity. The advantage to the use of color for communication is that there is an increased capacity to convey information in the message. The disadvantage is that the information contained in the color channel may not be perceived by approximately eight percent of the population who have impaired color vision. Misperceiving color information may result in not seeing such important messages as headings on a spreadsheet or the distinct colored sections in a pie chart. This paper explains the technological and perceptual problems associated with the use of color computer display systems, and then offers a solution for the effective use of color regardless of the viewer's ability to perceive color. (14 references) (Author/DB)

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Using Color as Information in Computer Displays:  
Problems with Perception and Communication

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Running Head: COMPUTERS AND COLOR PERCEPTION

BIOGRAPHICAL NOTE

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### Abstract

The advancement of computer technology has reached the point where color monitors and color software is fast becoming the norm in our information society. Color is another channel for communication, and can be used for enhancement of both aesthetic characteristics and productivity. However, the use of color is both a boon and a bane for communication. The boon is the increased capacity to convey information in the message. The bane is that the information contained in the color channel may not be perceived by approximately eight percent of the population who have impaired color vision. Misperceiving color information may include not seeing such important messages as headings on a spreadsheet or the distinct colored sections in a pie chart. This paper explains the technological and perceptual problems associated with the use of color computer displays, and then offers a solution for the effective use of color regardless of the viewer's ability to perceive color.

Using Color as Information in Computer Displays:

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Color In Computers

Technical improvements in computing have led to increased speed and capacity and decreased size and cost. These technical improvements have also led to advances in software such that today there are more software genres, more choices within genres, and increased sophistication in the software choices. The interaction of these technical improvements and software advances has led to a world where more computers are being used in the home and at work in more ways than ever before .

In the area of display technology, significant improvements have been made in color capabilities to the point where high definition color monitors are becoming common. Software is being designed to utilize these advances in monitors. For example, the aesthetic advantages of bright and vivid colors and sharp detail has a great appeal to spread sheet users. Moreover Rice and Blair (1984) indicated that computer automation should increase productivity. MacDonald and Cole (1988) added color monitors to office automation because color organizes data and thus should increase productivity.

One important dimension of these uses is the interaction between people and computer. One aspect of this dimension is human visual perception, including color perception. Unfortunately, a significant percentage of the population has color impaired vision that reduces the perception of the color

channel and thus precludes or distorts the information carried in that channel. This paper discusses both the impairment and its simple solution.

### Color as Information

From a communication perspective, color is a channel to convey information. For example, different colors can (1) have different meaning (e.g., red means financial loss), (2) group like-items (e.g., yellow letters identify safety information), or (3) differentiate between parts of a whole (e.g., different colors are used to identify different sections of a pie chart).

Color is described as the single most valuable characteristic in appreciating and responding to the visual world around us. Color gives shape, form, solidity, and depth to what we see. Adding color to a visual image is considered a significant improvement to information exchange (Harris, 1984).

Central to the use of the computer as a communication medium is the manipulation of visual display information, including color. That is, both the software programmer and end-user of the software can now use color to create and enhance information exchange (Ware & Beatty, 1988). The key to using color for communication is to accurately transfer the intended meaning of color in the source to the perception of color in the receiver.

### Color Perception

The term used to identify human perception of color is colorimetry (Cruz-Coke, 1970). Among theories of colorimetry (e.g., trichromatic theory, opponent color theory), there is

general agreement that color is seen because the object we view reflects or emits a range of electromagnetic waves that are perceived by the human optic system (Glasstone, 1950).

Operationally, the reflected or emitted light waves are adjusted by the source to optimize physiological and psychological perception by the receiver (Wyszecki & Stiles, 1967).

This adjustment depends on three dimensions: hue, saturation, and luminance (Chapanis, 1965). Hue is the tint used to describe a color, such as the difference between red and blue. Saturation is the description of the purity or intensity of the hue: a hue can be described by how de-saturated it is with white as in the difference between dark green and fern green. Luminance is the brightness of an object, ranging from black to white as in the difference between dark grey and light grey.

The Committee on Colorimetry of the Optical Society of America (Evans, 1948) concluded that variance in hue, saturation, and luminance are highly correlated, and that these three dimensions produce contrast, which is perceived as information by individuals. Perception then is dependent on contrasts, which for people with normal color vision is determined by both differences in color (hue and saturation) and luminance. Such differences contain information, and so the luminance and chrominance channels are the means for communication.

#### The Color Perception Problem

Though color and luminance both have been shown to be effective mediums for the communication of information by

controlling hue, saturation, and luminance, there is one significant problem. Approximately eight percent of the male and one half of one percent of the female North American population has impaired color vision (McLaren, 1986). This impairment limits the effectiveness and accuracy of the information exchange via the chrominance channel.

Impaired color vision is when visual receptors do not respond to a hue or hues. While there are several causes for impaired color vision (e.g., deficient genes, pathological condition, trauma from an accident), the condition ranges from the total lack of color perception to the more common disability of not perceiving a few narrow visual frequencies (Linksz, 1964).

The totally color blind individual perceives no hues, only varying brightness. The partially color blind may (1) not perceive a hue or combination of hues, (2) perceive a hue with lower intensity, (3) not functionally discriminate between hues, or (4) mistake a combination of hues (i.e., yellow is perceived as magenta).

The color impaired viewer is at a disadvantage because they are physiologically unable to perceive the colors and thus cannot receive the intended information. For instance, if reference is made to a light blue section of a pie chart but the light blue section is not perceived by a color impaired individual, this individual will not acquire the intended information. Additionally, the visually impaired person may misinterpret the information if one color is perceived as another. For instance,

if the brown section of a pie chart is referenced and the visually impaired person attends to the red section, the intended information is not communicated while incorrect information is retained as "correct."

This paper assumes that the percentage of software programmers, end-users of these programs, and audience members viewing the product of the end-users will be equivalent to the population (i.e., eight percent of the male and one half of one percent of the female color computer users will be color impaired). With the rapidly expanding use of color capable computers and software, the incidence of information exchange problems due to impaired color perception is significant and would be expected to increase among all three groups of color computer users.

In sum, the problem of color perception is significant and will tend to increase. Other media have encountered this dilemma, and have produced a viable solution.

#### Color Use in Broadcasting

In the broadcast field, the deficiency of color perception has already been addressed and rectified. The television broadcaster uses luminance differences to communicate in black and white. For color pictures, the three primary hues (red, blue, green) and adjustments to the saturation for each hue are combined with the luminance information in an additive process<sup>1</sup>. That is, the luminance, hue, and saturation dimensions of a video signal are combined and controlled to produce a color picture (Wurtzel,



1983). Gabor (1962) reported that the color channel (i.e., hue and saturation) typically contains about 23% of the total information in a color broadcast picture. Thus, for the broadcaster, color is an embellishment: broadcasters put critical information in the luminance channel (black and white picture) and then colorize the picture to augment the luminance information. Today, almost all television software contain controls for the luminance and chrominance channels while both waveform monitors and black and white video monitors are used as final checks to insure that key information is communicated in the luminance channel. For example, most character generators that create the words inserted over news pictures are first typed on a black and white video monitor and then checked for aesthetics on a color monitor: the critical information is first insured in the monochrome picture and then colorized.

#### Color Use With Computers

Color computer monitors use the same additive process the television industry does (Linksz, 1964). In both computer monitors and computer projectors, the cathode ray tube (and associated electronics) is roughly equivalent to television monitors in that it is a light emitting device where rays of red, blue, and green (with saturation differences) are combined to produce almost all colors including white (H. W. Sams & Co., 1973). The absence of a color channel (hue and saturation) leaves all the visual information to be carried in the luminance channel. Thus, the luminance and chrominance channels are separate and

independent but the luminance channel is primary because (1) the chrominance channel is added to the luminance channel and (2) without a luminance channel you cannot have a picture.

Originally, the guidelines for color selection in the computer world were given from a technical programming perspective (Sproull, Sutherland, and Ullner, 1985). This perspective attended to the capabilities of monitors and encoding hardware rather than the human user. Several reasons for this original decision are (1) most of the displays were monochrome (e.g., white, green, or amber screens), (2) these monitors had external controls for brightness and contrast (video gain), (3) there were few software programs that had the ability to colorize the visual information, and (4) the few color monitors in existence had an external control for color balance. This technical perspective tended to obscure the notion that the primary information channel was the luminance channel and that color was to be added to the luminance channel and so was secondary.

While today's high definition color monitors have much greater capacity for picture definition and accurate color reproduction, current software for these monitors may be still using the old technical perspective such that the new software (1) ignores the notion that the primary communication channel is the luminance channel and that the color channel is an addition to the luminance channel, (2) fails to remember that the viewer does not have universal color perception abilities, and (3) would underutilized the capabilities of the computer hardware. For

example, one solution is to use different hues but keep saturation and luminance constant (Stark, 1990). A second resolution is to use different hues and different saturations but keep the luminance amplitudes constant. A third solution is to have variable saturation with constant luminance and one hue.

While any of these combinations produce color pictures that have usable information for the person with normal color vision, the color weak individual is confronted with several problems. First, the color impaired may be forced to perceive information based only on hues which they cannot see. Second, they may be forced to perceive information based on saturation differences, which may be missing because the all the colors have a uniform saturation level. Third, they be left to perceive information based on luminance differences which may be missing because all colors have a uniform luminance level. Fourth, the de-saturation of the hues may be perceived as video noise in the luminance channel (Evans, 1948).

In sum, the new visual display devices have great capacity for color visuals but most of the software uses inadequate color system controls that do not accommodate individuals with color impairment. With the increasing use of color computers at home and in industry, the occurrence of color perception problems will tend to escalate. The prior technical perspective does not resolve this problem, and so a new software oriented solution is needed.

#### Solution to Problem

The key to accommodating both the normal and color impaired viewer is to produce visible contrasts by controlling the combination of hue, saturation, and luminance.

One unrealistic solution is to have each color impaired user adjust the hardware and software for their individual impairment. Unfortunately, this cannot be accomplished in a group situation where everyone is viewing a common screen. Moreover, if the impaired user makes corrections based on their impairment, then these corrections may misinform the normal viewer who may incorrectly perceive the corrections.

The only realistic solution comes from Sproull, Sutherland, and Ullner (1986), who have specified computer software subroutines (hsvrgb and rgbhsv) to allow the independent control of hue, saturation, and luminance of visual content. This control allows for contrasts to be created in the luminance channel with the subsequent addition of color channel information. Remember, as the perception of color is variable among the population, the solution for both the normal and color impaired user rests with the control of luminance because variance in luminance directly creates perceivable contrast for both the normal and color impaired user. For the color impaired, de-saturation may not create enough contrast to make the visuals intelligible, de-saturation is perceived as video noise, and variance in hue is the cause of the problem in the first place. Once the luminance channel contains the pertinent and salient information, then color can be added. The luminance channel is primary and the

chrominance channel is secondary for information transmission.

This paper further argues that these subroutines should be included in all software to support the control of visual displays (via monitor or projector). End-users should have access to hue, saturation, and luminance controls and be educated about the impact of these controls on audience visual intelligibility.

That color perception problems or the loss of the chrominance channel could lead to missing information via the computer, with subsequent catastrophic consequences, has already been recognized and resolved in areas beyond the television field. For example, newer aircraft are now using color VDTs to contain information important for flying that aircraft. Color is included in the VDT to provide information to aid the pilot (MacDonald and Cole, 1988). They report that the addition of hue and saturation information to the basic luminance information was a deliberate decision because color made the information easier to organize. Color is used to increase efficiency but is not allowed to contain critical information which is allocated only to the luminance channel of the cockpit VDT: should the color channel fail, vital information would not be lost.

### Conclusion

Programmers and end-users employ the color channel in computer displays to communicate information. We assume that a significant percent of software programmers, end-users of the software, and audiences of computer messages have impaired color perception which creates an information exchange problem. Driving

this problem is the omission of or ignorance about software controls of the hue, saturation, and luminance to create messages for both the normal and color impaired viewer. This situation forces the color impaired to perceive information by differences in hue (their impairment) or saturation (seen as video noise) while the luminance channel may not have any differences and so no contrasts are which can communicate information. The solution is to communicate visual information with luminance differences and then add hue and saturation to enhance this difference. Controlling luminance, hue, and saturation allows both the color deficient and the color normal viewer to perceive the communicated information.

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Author Notes

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Footnote

1. When red, blue and green light is electronically mixed in equal amounts, white light is produced, and hence one notion of an additive process.